S
627.83
N7wcdm
2001

WILLOW CREEK DAM

MANUAL FOR OPERATION AND MAINTENANCE

STATE DOCUMENTS COLLECTION
JUL 31 2001
MONTANA STATE LIBRARY
1515 E. 6th AVE.
HELENA, MONTANA 59620

State Water Projects Bureau
Water Resources Division
Department of Natural Resources and Conservation
48 North Last Chance Gulch
P. O. Box 201601
Helena, MT 59620-1601

Initial Publication March 1995
Revised July 2001

MONTANA STATE LIBRARY
3 0864 0015 5119 4

WILLOW CREEK DAM

MANUAL FOR OPERATION AND MAINTENANCE

State Water Projects Bureau
Water Resources Division
Department of Natural Resources and Conservation
48 North Last Chance Gulch
P. O. Box 201601
Helena, MT 59620-1601

Initial Publication March 1995
Revised July 2001

Digitized by the Internet Archive
in 2015

https://archive.org/details/willowcreekdamma2001mont

TABLE OF CONTENTS

OVERVIEW 1
General Location Map (Figure 1) 3
Project Area Map (Figure 2) 4
Dam General Layout Map (Figure 3) 5

STATISTICAL INFORMATION 7

OPERATING PROCEDURES 11
Method and Schedule of Operation 11
Safe Drawdown 12
Limits of Appurtenances 12
Dam Operator 12
Storage Determination 13
Weather Monitoring 14
Interaction with Other Dams 14
Emergency 15

INSPECTION AND MONITORING 17
Structural Features Inspection 17
Riprap Inspection 18
Seepage Monitoring 18

MAINTENANCE 21
Routine Maintenance 21
Annual Maintenance 22
Record Keeping 22

REFERENCES 25

APPENDICES 27
A. RATING CURVES AND TABLES A1
Table 1. TOTAL STORAGE TABLE A2
Table 2. SPILLWAY RATING CURVE AND TABLE A4
B. INSPECTION REPORT FORM B1
C. O&M MANUAL DISTRIBUTION LIST C1
D. PROJECT DRAWINGS D1

OVERVIEW

Willow Creek Dam is located in Madison County, 3 stream miles southwest of the line separating Madison and Gallatin Counties. The project is approximately 10 miles upstream of the town of Willow Creek, 4 miles east of the town of Harrison, and 17 miles upstream of the city of Three Forks. The reservoir is fed by Willow Creek from the west, Dry Hollow Creek from the southwest, and Norwegian Creek from the south (see Figures 1 and 2). Figure 3 provides a general layout of the dam, spillway and outlet works.

The dam is owned by the Montana Department of Natural Resources and Conservation (DNRC) and is managed by the State Water Projects Bureau (SWPB) of the DNRC. The Willow Creek Water Users Association (herein called the "association") operates and maintains the dam.

The earthfill dam was constructed in 1938. The dam is 105 feet high and 453 feet long. The dam's outlet works is located in the left abutment. The outlet conduit is a 60-inch diameter straight-legged horseshoe section, approximately 363 feet long. The conduit ends at the tunnel downstream portal. A concrete chute, with semicircular side slopes extends approximately 20 feet downstream of the portal. The outlet works consist of an 8-foot diameter dry well containing a 54-inch diameter emergency gate valve and a 54-inch diameter butterfly operating valve. The operating gate is controlled from the top of the tower, while the emergency gate is controlled at the bottom of the tower. The gate tower is covered by a locked gatehouse.

The spillway is located in rock at the left abutment. The spillway was originally rock-lined, but it was reconstructed with a concrete liner in 1945. The unlined approach channel to the

uncontrolled concrete ogee crest is short and unobstructed. There is no log boom upstream of the spillway. The spillway is 90 feet wide at the crest and tapers to 50 feet wide at the toe with a maximum capacity of 8,300 cubic feet per second (cfs).

Water from the reservoir is used for irrigation water supply. The reservoir also is used for water-based recreation.

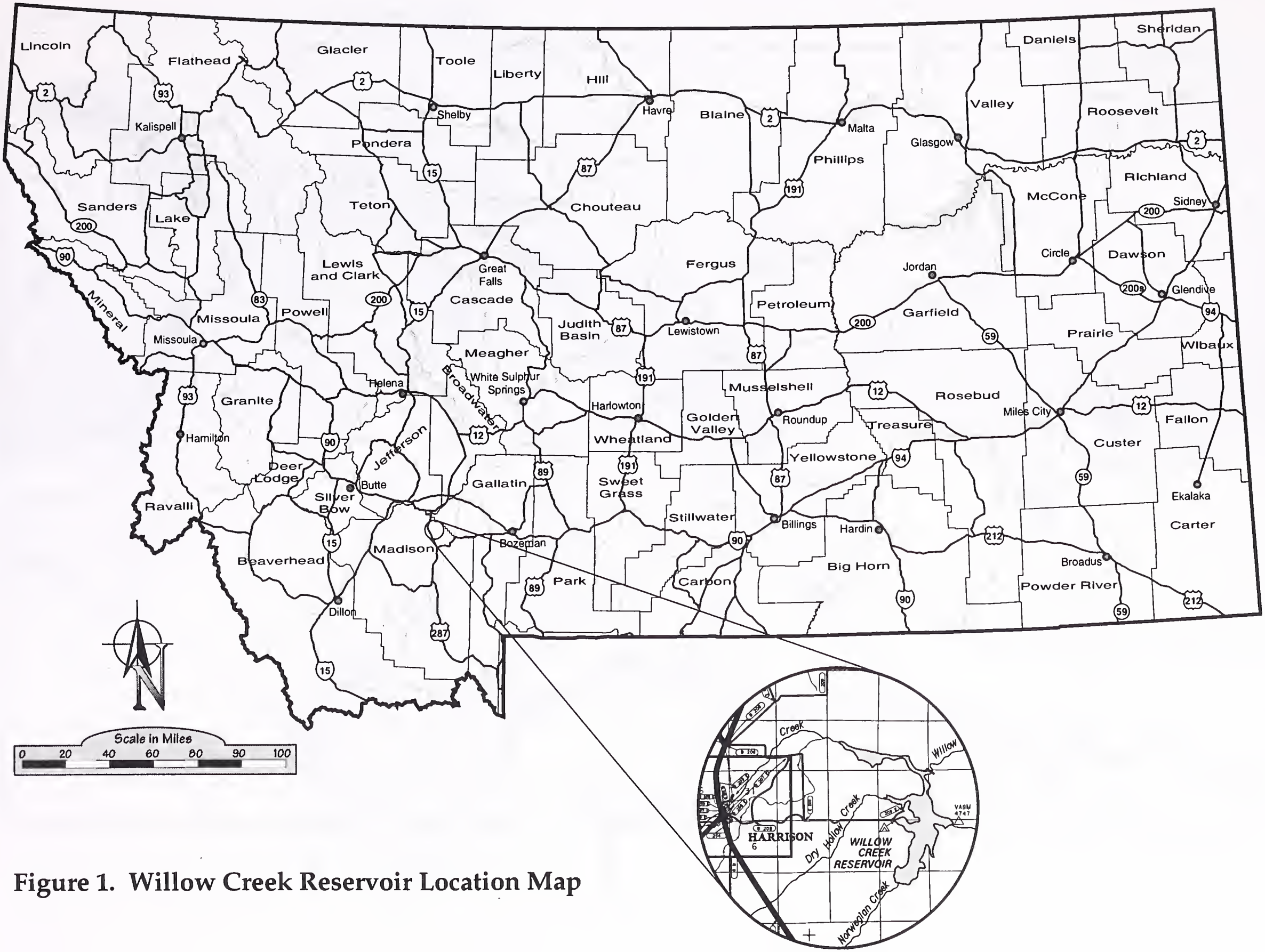


Figure 1. Willow Creek Reservoir Location Map

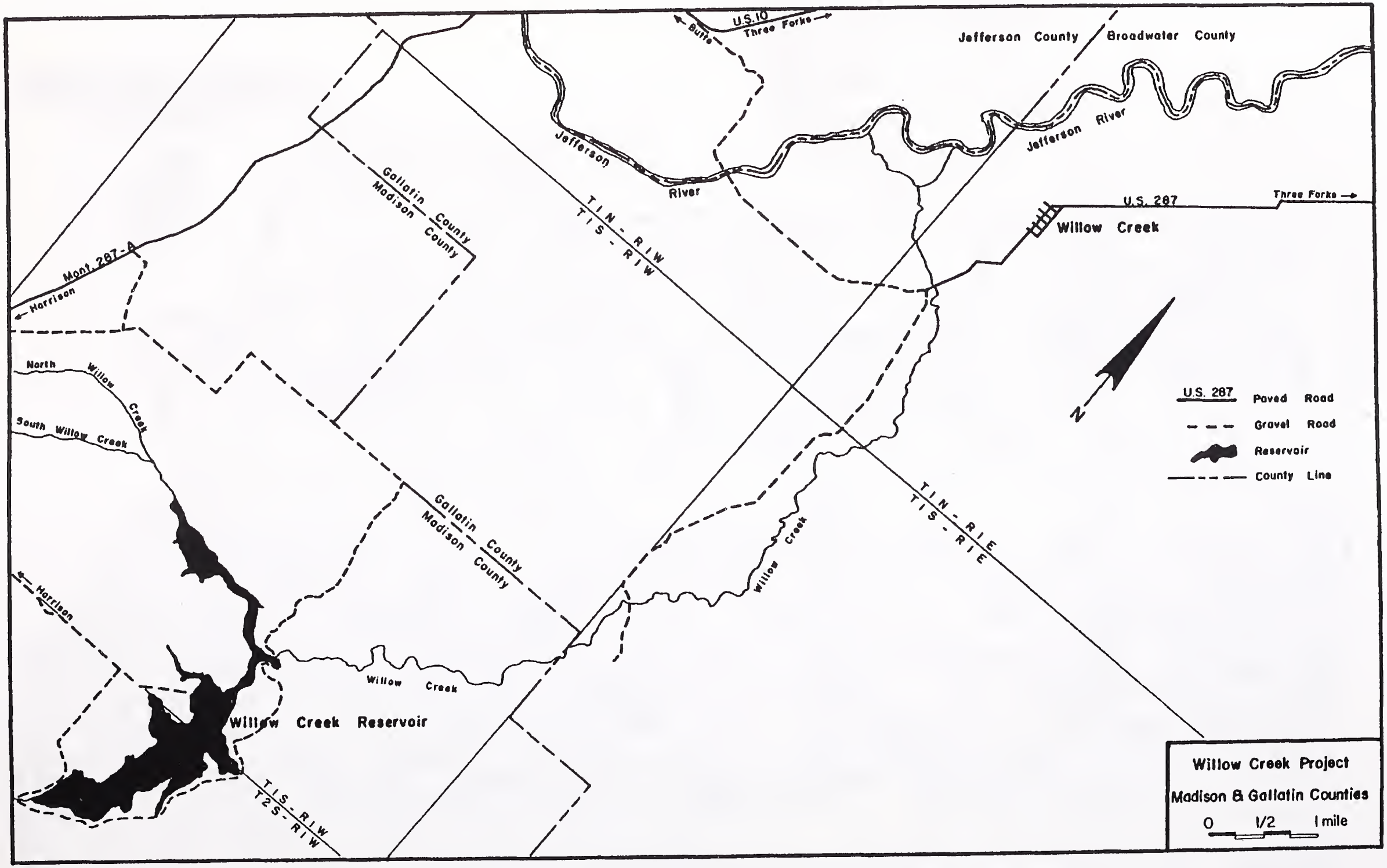


Figure 2. Willow Creek Dam Project Map

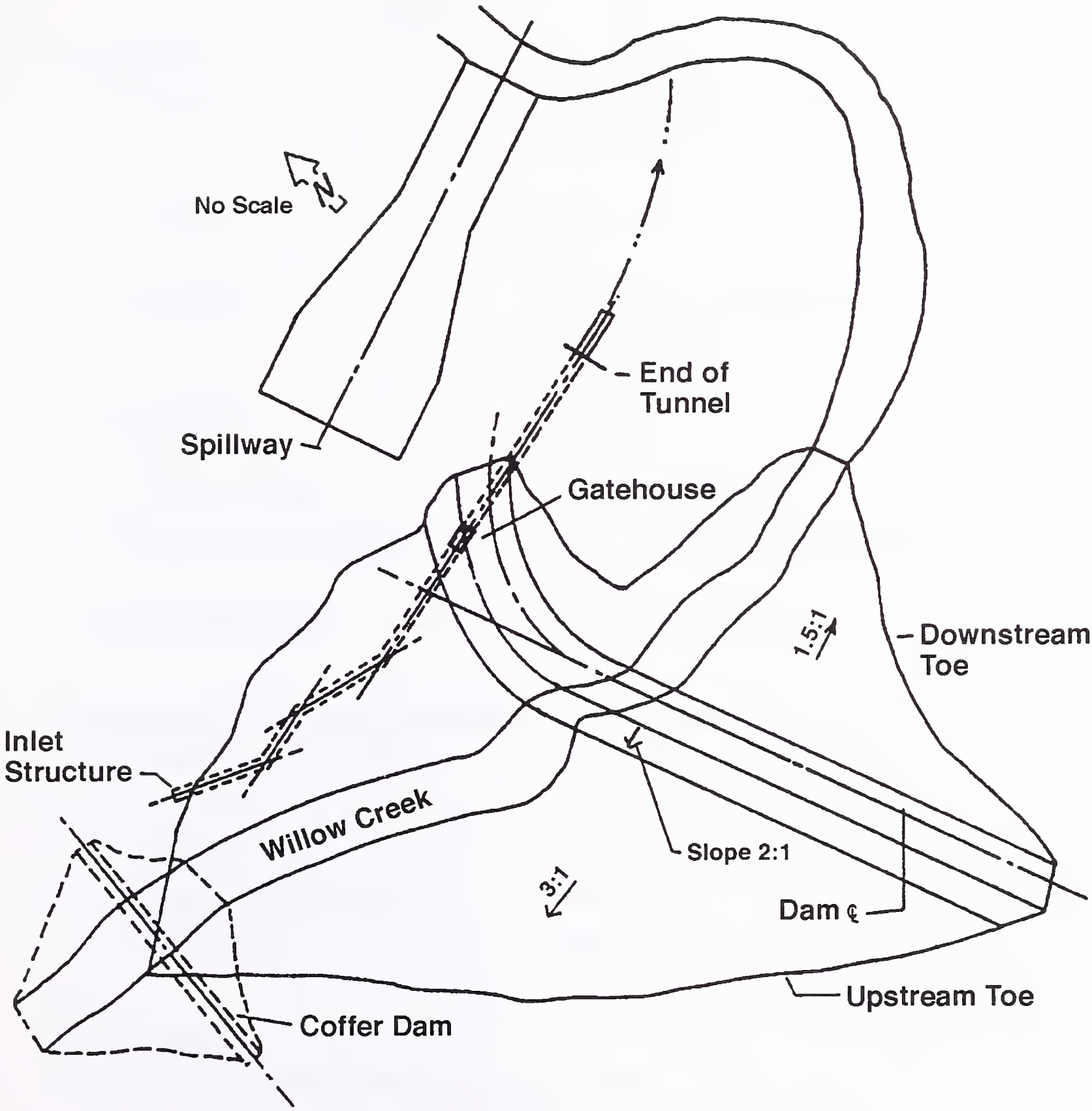


Figure 3. Willow Creek Dam General Layout

STATISTICAL INFORMATION

1. General

a.	Owner	Montana Department of Natural Resources and Conservation (DNRC)
b.	Operator	Willow Creek Water Users Association
c.	Location	Section 35, Township 1 South, Range 1 West, MPM (dam location)
d.	Latitude Longitude	45.71° 111.70°
e.	County--State,	Madison--Montana
f.	Watershed Location,	Willow Creek, Jefferson River Basin
g.	Drainage Area,	155 square miles

2. Principal Elevations (feet above mean sea level)

a.	Minimum Dam Crest	4,744.5 feet
b.	Normal Full Pool	4,736.0 feet
c.	Spillway Crest	4,736.0 feet
d.	Outlet Design Invert	4,666.5 feet
e.	Toe of Dam	4,639.5 feet

3. Reservoir

a.	Length of Maximum Pool (north and south--approximate)	2.0 miles
b.	Length of Maximum Pool (east and west--approximate)	1.6 miles
c.	Maximum Reservoir Level of Record (June 30, 1963)	4, 736.7 feet (19,230 acre-feet)
d.	Surface Area at Normal Pool	885 acres

4. Storage

a. Maximum Storage (pool at dam crest)	26,600.acre-feet
b. Active Storage (pool at spillway crest)	18,000 acre-feet
c. Maximum Surcharge (from spillway crest to dam crest)	8,600 acre-feet

5. Hydrology

a. Probable Maximum Flood (PMF) (March, 1993)	61,300 cfs (170,090 acre-feet)
b. 500-Year Return Period Flood	4,618 cfs
c. 100-Year Return Period Flood	2,936 cfs
d. Maximum Inflow of Record (1938-1992) at USGS gage 06035000 (2.2 miles upstream from the dam on Willow Creek	813 cfs

6. Embankment (Dam)

a. Type	Earthfill
b. Hydraulic Height	105 feet
c. Crest Length	453 feet
d. Crest Width	28 feet
e. Downstream Slope	1v on 1.5h
f. Upstream Slope	1v on 3.0h

7. Outlet Works

a. Size	60-inch, straight legged horseshoe-shaped, reinforced concrete and cast iron
b. Length	362 feet
c. Control	54-inch diameter gate valve upstream (emergency gate)

	and a 54-inch butterfly valve (operating gate)--gate valve is operated from the bottom of a 96-inch diameter tower, while the butterfly valve is operated from the top of the tower
d. Discharge Capacity (pool at dam crest)	700 cfs
e. Trashrack	Yes

8. Spillway

a. Location	Left abutment
b. Type	Uncontrolled ogee
c. Width	90 feet tapering to 50 feet
d. Length	240 feet
e. Capacity (pool at dam crest)	8,300 cfs

OPERATING PROCEDURES

The association operates Willow Creek Dam and Reservoir to provide an adequate supply of irrigation water to meet contracts with water users without exceeding safe storage or flow levels.

METHOD AND SCHEDULE OF OPERATION

The association's goal is to have the reservoir full before contract holders start putting in calls for water. Except during very dry years, the reservoir fills, and some water flows over the spillway. The date the irrigation releases begin varies from year to year, with late April typically being the earliest. Irrigation releases usually end by October 1, as specified in the water purchase contracts. The actual dates that releases begin and end depend on a year's climatological and hydrological conditions.

Maximum Winter Storage: The maximum reservoir elevation for winter storage is 4,726.0 feet with 10,924 acre-feet of storage. This winter maximum helps prevent damage to the riprap and embankment from wind-driven waves and ice.

Minimum Winter Storage: The minimum reservoir elevation for winter storage is 4,676.0 feet with 498 acre-feet of storage. This winter minimum helps prevent ice damage to the inlet structure for the outlet works.

Minimum Outlet Discharge: Fish, Wildlife and Parks (FW&P) recommends a minimum flow of 14 cfs be maintained at the dam outlet. FW&P cautions that stoppage of dam releases in winter is a serious problem to downstream fishery.

SAFE DRAWDOWN

Because the stability of Willow Creek Dam has not been thoroughly investigated, SWPB recommends that drawdown rates not exceed one foot per day.

LIMITATIONS OF APPURTENANCES

Appurtenances at Willow Creek dam are the outlet works and the spillway. With the reservoir at the dam crest, the capacity of the outlet works is 700 cfs and the spillway is 8,300 cfs. Combined maximum discharge of the outlet works and spillway is 9,000 cfs.

When the discharge of the spillway is at or near 8,300 cfs, the sidewalls of the chute may be overtopped. The extent of such overtopping and the resulting damage to the spillway are unknown. An outlet-rating table is shown in Appendix A.

DAM OPERATOR

The responsibility for the daily operation of the dam and reservoir rests with the association and its dam operator. The dam operator is generally authorized to operate the reservoir to meet the association's goal of providing an adequate supply of irrigation water to meet water user's contracts without exceeding safe storage and flow levels. The dam operator's specific responsibilities are to:

1. Operate the mechanical features of the outlet works. The outlet gates are normally operated manually with a hand crank.
2. Coordinate filling of the reservoir and the release of water.
3. Notify the SWPB of any unusual occurrences such as vandalism, impending floods, structure failure, or excessive seepage.
4. Perform various maintenance tasks.

5. Monitor weather conditions.
6. Monitor seepage.

Typically, the out-going dam operator, the association and the SWPB train a new dam operator. The dam operator's training focuses on operating the mechanical gates, measuring the storage levels, measuring the rate of water release, observing the dam and the area for any unusual conditions, and record keeping.

The outlet works are intended to be used for controlling the release of irrigation water and not for providing emergency relief.

The dam operator normally is available to observe the dam and perform operating functions daily during the times of rapid reservoir filling. During the remainder of the filling and irrigation seasons, the operator is at the dam three to five times per week. At other, times the operator visits the dam weekly or monthly. The dam operator normally does not visit the dam during the winter months due to poor access because of snow.

Communication among the dam operator, the association, and the SWPB usually takes place by telephone. Although no routinely available, radio communication way be established during emergencies or unusual occurrences, radio communication may be established so that the dam operator can speak directly with county authorities and communicate indirectly with the SWPB staff (see *Willow Creek Dam Emergency Plan*).

STORAGE DETERMINATION

Reservoir volume and water surface elevation are determined using a level off the spillway crest and measuring down to the water surface. The vertical distance is subtracted from the

spillway crest elevation to determine the water surface elevation. Volume of the reservoir is then determined from the Total Storage Table (Table 1) in Appendix A.

The reservoir volume and water surface elevation can also be determined by taking a slope measurement. Slope pins (rebar) were installed upstream of the dam on the east side of the reservoir along the road which slopes down to the reservoir. The pins were installed in 1996, but a Slope-Elevation-Storage Table has not been created at this point.

WEATHER MONITORING

The dam operator monitors weather conditions through local weather forecasts and the National Weather Service (NWS).

If severe flooding is anticipated, the NWS Great Falls Office (406-453-2081 or 406-453-4561) should be contacted for information about the storm, such as the estimated storm intensity and duration, runoff duration (above base flow), and total flood volume of the storm in the Willow Creek drainage.

INTERACTION WITH OTHER DAMS

Except for irrigation diversion dams, Toston Dam and Canyon Ferry Dam are the next dams downstream from Willow Creek Dam. The safety of these dams is not affected by the normal operation of Willow Creek Dam.

The two largest dams located upstream of Willow Creek Dam are Cataract Creek Dam (maximum storage 1,800 acre-feet and maximum outlet/spillway capacity 1,410 cfs) and Norwegian Creek Dam (maximum capacity 1,910 acre-feet and maximum outlet/spillway capacity 1,200 cfs). Because of the surcharge of

Willow Creek Reservoir, the normal or emergency operation of these dams is not a safety concern to the Willow Creek Dam.

Therefore, interaction with other dams is not a concern during normal operations.

EMERGENY

If it appears that Willow Creek Dam will breach, or during other emergency operations, the dam operator will initiate the **Willow Creek Dam Emergency Plan** and notify the operators at Toston Dam (**1-406-266-3869**) so that they can initiate their Emergency Plan.

INSPECTION AND MONITORING

The SWPB inspects the dam annually. Appendix B includes an example of a SWPB inspection report form. In addition to annual inspections, SWPB personnel will inspect the dam and reservoir during and after heavy runoff and severe rainstorms and windstorms, during high storage periods, and after an earthquake. The embankment is not monitored by instrumentation.

STRUCTURAL FEATURES INSPECTION

Structural features include the embankment, gatehouse, outlet works, and spillway. The SWPB will inspect these structures annually as part of its inspection program. Items to be checked or noted include, but are not limited to:

1. Embankments
   a. Erosion gullies in dam embankment
   b. Damage from burrowing animals or vegetation
   c. Displacement or loss of riprap protection
   d. Displacement of fill, sinkholes, slumps, or other items
   e. Any seepage on downstream or base of embankment
2. Gatehouse - Any damage or vandalism
3. Outlet Works
   a. Any differential settlement or movement resulting in cracking of the conduit
   b. Erosion of the seals or concrete by cavitation immediately downstream of the gates
   c. Major seepage of water into the conduit
   d. Major deterioration of exposed concrete due to freeze/thaw cycles or sulfate reactions
   e. Operation of both gates through a full cycle
   f. Free, unobstructed operation of the air vent

g. Corrosion of any metal

h. Proper lubrication and cleaning of the pedestals

4. Spillway
   a. Deterioration of concrete

   b. Separation or movement of joints

   c. Erosion of the spillway chute, backfill behind the walls, or stilling basin

   d. Blockage of the approach or exit channel

RIPRAP INSPECTION

The riprap along the face of the dam should be at least 30 inches thick. Immediately after the occurrence of high water, SWPB personnel will inspect the riprap and determine if additional riprap is necessary.

SEEPAGE MONITORING

Minor seepage has been observed downstream of the toe near the right abutment in the backwater pool. It is unclear whether the water is coming from springs or from bank storage in the gravels around the pool. No indication of sediment moving with the water has been observed.

Seepage of up to about 5 to 10 gallons per minute has been observed seeping from the bedrock joint above and left of the outlet tunnel portal. No indication of sediment moving with the water has been observed. The seepage appears to be directly connected to the reservoir. As the reservoir pool lowers, the seepage decreases.

These areas of seepage will be observed and monitored by the SWPB and dam operator during regular visits, and by the SWPB during annual inspections. To date, no seepage measuring equipment has been installed at the dam.

MAINTENANCE

The association is responsible for the routine maintenance of the project. In addition, the SWPB may identify items that need maintenance or repair during the annual inspection

ROUTINE MAINTENANCE

To protect the dam and keep it in good working order, the dam operator during regular visits to the dam will watch for and identify any potential maintenance requirements. As soon as a need is identified, the dam operator needs to schedule and perform the routine maintenance.

Items that may occasionally need attention include, but are not limited to:

1. *Lubrication of gate-operating mechanisms.*
2. *Debris or silt restricting the spillway inlet or the outlet works.* Accumulated debris that could affect the operation of these appurtenances will be removed at once, with all debris removed at least annually.
3. *Erosion gullies on embankment.* Development of erosion gullies will be checked immediately. Gullies will be filled, compacted, and seeded. Particular attention will be paid to the abutment contact areas and the downstream faces where four-wheel drive tracks may become a problem.
4. *Rodent damage.* The rodents will be removed or destroyed, and any burrows holes should be filled immediately.
5. *Upstream slope riprap.* Reservoir riprap normally will be observed annually, but may occasionally need repairs because of high water or wave action.
6. *Vegetative cover on downstream slopes.* Good vegetative cover will be maintained, but large brush will be removed.

7. *Noxious weeds.* Noxious weeds on and around the dam embankment and around the reservoir should be sprayed at least on an annual basis.
8. *Clean concrete structure wall tops.* Spillway and outlet tunnel portal wall tops should be clear of any dirt, rocks, grass, brush, and any overhanging vegetation or trees.
9. *Repair joints and seal crack in the concrete structures.*

ANNUAL MAINTENANCE

The SWPB conducts annual inspections of Willow Creek Dam and Reservoir. During these inspections, any items that require maintenance will be identified and recorded. Items that may need annual maintenance include the spillway, outlet works, gates, riprap, roads, and gatehouse. Any other routine items that need immediate attention, such as the need to remove trees or brush, will also be noted.

After the annual inspection, the SWPB sends the association a Dam Safety Inspection Report and a Maintenance Schedule Report. These reports identify items that need maintenance and provide a schedule of when the maintenance tasks need to be completed. The association is responsible for performing the maintenance items within the times specified.

The dam operator or association members may perform the maintenance tasks. However, major repairs will likely to be handled by a contractor. The SWPB may assist in contracting for repairs and may supervise the repair work.

RECORD KEEPING

The SWPB will maintain records, including photographs, of all inspections and maintenance requirements. These records also include seepage observations. Anyone who wants to review these

records may do so in the SWPB's office at the Department of Natural Resources and Conservation in Helena.

The dam operator will keep records of the reservoir elevation, seepage observations or measurements, and any unusual conditions. These records may be reviewed at the dam operator's house.

REFERENCES

CH2M Hill. May 1980. *Phase 1 Inspection Report, National Dam Safety Program, Willow Creek Dam, Willow Creek, Montana, Madison County, MT-22.* Prepared for the State of Montana (DNRC) under the U.S. Army Corps of Engineers' National Dam Safety Program.

Miller, Roy, Willow Creek dam operator. October 1993.

Omang, R. J. July 1992. *Analysis of the Magnitude and Frequency of Floods and the Peak-Flow Gaging Network in Montana.* Water Resources Investigations Report 92-4048. U. S. Geological Survey.

Personal telephone communications with Jim Beck, Helena Regional Office Engineer, DNRC, Helena.

Shields, R. R., J. R. Knapton, M. K. White, T. M. Brosten, and C. L. Chambers. 1993. *Water Resources Data, Montana, Water Year 1992.* Water Data Report MT-92-1. U.S. Geological Survey.

APPENDICES

APPENDIX A

RATING CURVES AND TABLES

TABLE 1. TOTAL STORAGE CAPACITY IN ACRE-FEET

WILLOW CREEK RESERVOIR

Elevation	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
4666						269	271	273	274	276
4667	278	280	282	284	286	288	289	291	293	295
4668	297	299	301	303	305	307	308	310	312	314
4669	316	318	320	322	324	326	327	329	331	333
4670	335	338	340	343	345	348	351	353	356	358
4671	361	364	366	369	371	374	377	379	382	384
4672	387	390	392	395	397	400	403	405	408	410
4673	413	416	418	421	423	426	429	431	434	436
4674	439	442	444	447	449	452	455	457	460	462
4675	465	468	472	475	478	482	485	488	491	495
4676	498	501	505	508	511	515	518	521	524	528
4677	531	534	538	541	544	548	551	554	557	561
4678	564	567	571	574	577	581	584	587	590	594
4679	597	600	604	607	610	614	617	620	623	627
4680	630	634	639	643	648	652	656	661	665	670
4681	674	678	683	687	691	696	700	704	708	713
4682	717	721	726	730	734	739	743	747	751	756
4683	760	764	769	773	777	782	786	790	794	799
4684	803	807	812	816	820	825	829	833	837	842
4685	846	851	856	862	867	872	877	882	888	893
4686	898	903	909	914	919	925	930	935	940	946
4687	951	956	961	967	972	977	982	987	993	998
4688	1,003	1,008	1,014	1,019	1,024	1,030	1,035	1,040	1,045	1,051
4689	1,056	1,061	1,067	1,072	1,078	1,083	1,088	1,094	1,099	1,105
4690	1,110	1,117	1,124	1,130	1,137	1,144	1,151	1,158	1,164	1,171
4691	1,178	1,185	1,192	1,199	1,206	1,213	1,220	1,227	1,234	1,241
4692	1,248	1,255	1,262	1,269	1,276	1,283	1,290	1,297	1,304	1,311
4693	1,318	1,325	1,332	1,339	1,346	1,353	1,360	1,367	1,374	1,381
4694	1,388	1,395	1,402	1,410	1,417	1,424	1,431	1,438	1,446	1,453
4695	1,460	1,469	1,478	1,488	1,497	1,506	1,515	1,524	1,534	1,543
4696	1,552	1,561	1,570	1,580	1,589	1,598	1,607	1,616	1,626	1,635
4697	1,644	1,653	1,662	1,672	1,681	1,690	1,699	1,708	1,718	1,727
4698	1,736	1,745	1,754	1,764	1,773	1,782	1,791	1,800	1,810	1,819
4699	1,828	1,837	1,846	1,856	1,865	1,874	1,883	1,892	1,902	1,911
4700	1,920	1,932	1,945	1,957	1,970	1,982	1,994	2,007	2,019	2,032
4701	2,044	2,056	2,069	2,081	2,094	2,106	2,118	2,131	2,143	2,156
4702	2,168	2,180	2,193	2,205	2,218	2,230	2,242	2,255	2,267	2,280
4703	2,292	2,304	2,317	2,329	2,342	2,354	2,366	2,379	2,391	2,404
4704	2,416	2,428	2,441	2,453	2,466	2,478	2,490	2,503	2,515	2,528
4705	2,540	2,559	2,578	2,597	2,616	2,636	2,655	2,674	2,693	2,712
4706	2,731	2,750	2,769	2,789	2,808	2,827	2,846	2,865	2,885	2,904
4707	2,923	2,942	2,961	2,980	2,999	3,019	3,038	3,057	3,076	3,095
4708	3,114	3,133	3,152	3,172	3,191	3,210	3,229	3,248	3,268	3,287
4709	3,306	3,325	3,344	3,363	3,382	3,402	3,421	3,440	3,459	3,478
4710	3,497	3,536	3,574	3,613	3,651	3,690	3,729	3,767	3,806	3,844

TABLE 1. TOTAL STORAGE CAPACITY IN ACRE-FEET (continued)
WILLOW CREEK RESERVOIR

Elevation	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
4711	3,883	3,922	3,960	3,999	4,037	4,076	4,114	4,153	4,191	4,230
4712	4,268	4,307	4,345	4,384	4,422	4,461	4,500	4,538	4,577	4,615
4713	4,654	4,693	4,731	4,770	4,808	4,847	4,885	4,924	4,962	5,001
4714	5,039	5,078	5,116	5,155	5,193	5,232	5,271	5,309	5,348	5,386
4715	5,425	5,466	5,508	5,549	5,590	5,632	5,673	5,714	5,755	5,797
4716	5,838	5,889	5,941	5,992	6,043	6,095	6,146	6,197	6,248	6,300
4717	6,351	6,392	6,434	6,475	6,517	6,558	6,599	6,641	6,682	6,724
4718	6,765	6,806	6,848	6,889	6,930	6,972	7,013	7,054	7,095	7,137
4719	7,178	7,209	7,241	7,272	7,303	7,335	7,366	7,397	7,428	7,460
4720	7,491	7,548	7,605	7,663	7,720	7,777	7,834	7,891	7,949	8,006
4721	8,063	8,120	8,177	8,235	8,292	8,349	8,406	8,463	8,521	8,578
4722	8,635	8,692	8,749	8,806	8,863	8,921	8,978	9,035	9,092	9,149
4723	9,206	9,263	9,320	9,378	9,435	9,492	9,549	9,606	9,664	9,721
4724	9,778	9,835	9,892	9,950	10,007	10,064	10,121	10,178	10,236	10,293
4725	10,350	10,407	10,465	10,522	10,580	10,637	10,694	10,752	10,809	10,867
4726	10,924	10,981	11,039	11,096	11,154	11,211	11,268	11,326	11,383	11,441
4727	11,498	11,555	11,613	11,670	11,728	11,785	11,842	11,900	11,957	12,015
4728	12,072	12,129	12,187	12,244	12,302	12,359	12,416	12,474	12,531	12,589
4729	12,646	12,703	12,761	12,818	12,876	12,933	12,990	13,048	13,105	13,163
4730	13,220	13,300	13,379	13,459	13,539	13,619	13,698	13,778	13,858	13,937
4731	14,017	14,097	14,176	14,256	14,335	14,415	14,495	14,574	14,654	14,733
4732	14,813	14,893	14,972	15,052	15,132	15,212	15,291	15,371	15,451	15,530
4733	15,610	15,690	15,769	15,849	15,928	16,008	16,088	16,167	16,247	16,326
4734	16,406	16,486	16,565	16,645	16,725	16,805	16,884	16,964	17,044	17,123
4735	17,203	17,283	17,362	17,442	17,522	17,602	17,681	17,761	17,841	17,920
4736	18,000	18,101	18,202	18,304	18,405	18,506	18,607	18,708	18,809	18,911
4737	19,012	19,113	19,214	19,316	19,417	19,518	19,619	19,720	19,821	19,923
4738	20,024	20,125	20,226	20,328	20,429	20,530	20,631	20,732	20,833	20,935
4739	21,036	21,137	21,238	21,340	21,441	21,542	21,643	21,744	21,845	21,947
4740	22,048	22,149	22,250	22,352	22,453	22,554	22,655	22,756	22,857	22,959
4741	23,060	23,161	23,262	23,364	23,465	23,566	23,667	23,768	23,869	23,971
4742	24,072	24,173	24,274	24,376	24,477	24,578	24,679	24,780	24,881	24,983
4743	25,084	25,185	25,286	25,388	25,489	25,590	25,691	25,792	25,893	25,995
4744	26,096	26,197	26,298	26,400	26,501	26,600				

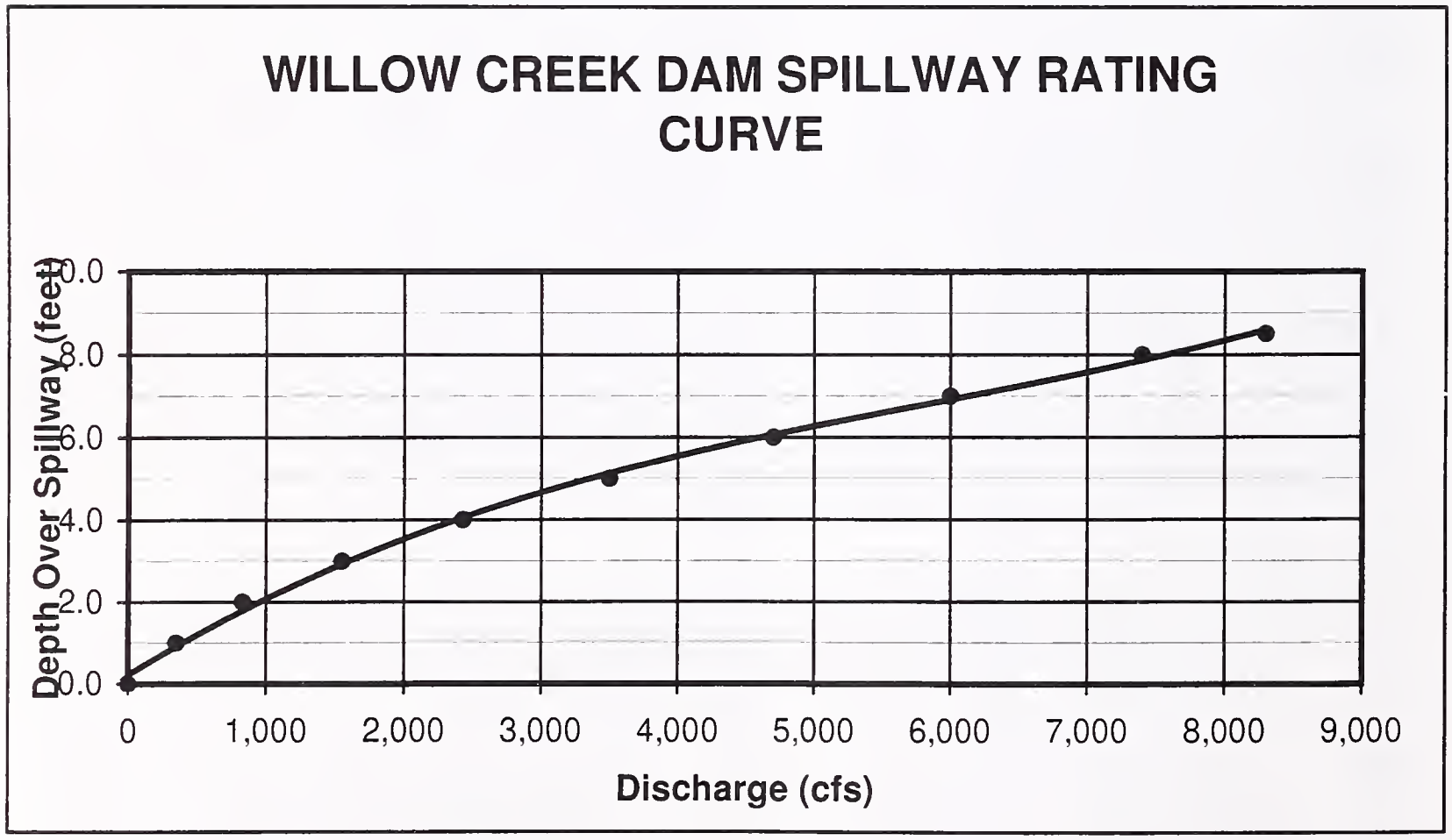
NOTE: Storage table based on 1938 original hand surveys of the reservoir.
Table prepared 4/19/01 by Bob Arrington based on 1995 O&M storage table.
Storage volume includes dead storage of 269 acre-feet.

Spillway crest	Elevation 4,736 feet	Storage 18,000 acre-feet
Dam Crest	Elevation 4,744.5 feet	Storage 26,600 acre-feet

TABLE 2. SPILLWAY DISCHARGE

WILLOW CREEK RESERVOIR

Depth Over Crest (feet)	Elevation (feet)	Discharge (cfs)
0.0	4,736.0	0
1.0	4,737.0	350
2.0	4,738.0	830
3.0	4,739.0	1,550
4.0	4,740.0	2,430
5.0	4,741.0	3,500
6.0	4,742.0	4,700
7.0	4,743.0	6,000
8.0	4,744.0	7,400
8.5	4,744.5	8,300



Note: Data from the Corps of Engineers Phase 1 Inspection Report (1980).

APPENDIX B

INSPECTION REPORT FORM

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
DAM SAFETY INSPECTION REPORT

NAME OF DAM _____
DATE INSPECTED_____

INVENTORY NO. _____ OWNER _____
HAZARD CATEGORY _____ OPERATOR _____
TYPE OF DAM _____ STREAM _____
YEAR BUILT _____ DRAINAGE AREA _____

Reservoir Storage Status

	Water Surface Elevation (feet)	Storage (acre-feet)
At time of inspection	_____	_____
At spillway crest	_____	_____
At min. dam crest elevation	_____	_____

ITEM	YES	NO	REMARKS
1. EMBANKMENT			
A. Crest -- Height= Length= Width=			
(1) Any visual settlements?			
(2) Any misalignments?			
(3) Any cracking?			
(4) Any traffic damage?			
(5) Other?			

ITEM	YES	NO	REMARKS

1. EMBANKMENT (continued)

B. Upstream Face -- Slope=

(1) Any erosion?			
(2) Any longitudinal cracks?			
(3) Any transverse cracks?			
(4) Is riprap protection adequate?			
(5) Any stone deterioration?			
(6) Any visual settlement, slumps, sloughing, depressions or bulges?			
(7) Adequate grass cover?			
(8) Debris on the dam face?			
(9) Other?			

C. Downstream Face--Slope=

(1) Any erosion?			
(2) Any longitudinal cracks?			
(3) Any transverse cracks?			
(4) Any visual settlement, slumps, sloughing, depressions or bulges?			
(5) Is the toe drain dry?			
(6) Are the relief wells flowing?			
(7) Any boils at the toe?			
(8) Any seepage areas?			
(9) Any traffic or animal damage?			
(10) Any burrowing animals?			
(11) Adequate grass cover?			
(12) Other?			

D. Amount and Type of Vegetation on the Dam

.

ITEM	YES	NO	REMARKS

2. ABUTMENT CONTACTS

A) Any erosion?			
B) Any visual differential movement?			
C) Any cracks?			
D) Any seepage present?			
E) Other?			

3. OUTLET WORKS

A. Intake Structure -- Size=

(1) Any settlement?			
(2) Any tilting?			
(3) Do concrete surfaces show:			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Exposed reinforcement?			
(4) Do joints show:			
a. Displacement or offset?			
b. Loss of joint material?			
c. Leakage?			
(5) Metal appurtenances:			
a. Any corrosion present?			
b. Any breakage present?			
(6) Trash rack?			
a. Condition?			
b. Anchor system secure?			
(7) Other?			

ITEM	YES	NO	REMARKS

3. OUTLET WORKS (continued)

B. Conduit -- Type = Size =

(1) Do concrete surfaces show:			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Exposed reinforcement?			
(2) Do joints show:			
a. Displacement or offset?			
b. Loss of joint material?			
c. Leakage?			
(3) Is the conduit metal?			
a. Any corrosion present?			
b. Protective coatings adequate?			
(4) Is the conduit misaligned?			
(5) Any calcium deposits?			
(6) Other?			

C. Gates and Tower

(1) Gates:			
a. Size: Operating: Emergency: b. Type: Operating: Emergency:			
(2) Controls operational?			
(3) Controls lubricated?			
(4) Operational problems?			
(5) Leakage around gates?			
(6) Condition of gate seals?			
(7) Any cavitation damage? If so, describe?			
(8) Describe air vent-size and condition.			

ITEM	YES	NO	REMARKS

3. OUTLET WORKS (continued)

C. Gates and Tower (continued)

(9) Is there a jet pump?			
a. Is it operational?			
b. Leakage?			
(10) Is the tower dry? _____ wet? __			
(11) Any seepage in the tower?			
(12) Condition of the tower?			
(13) Any safety problems?			
(14) Ladder in good condition?			
(15) Condition of the gatehouse?			
(16) Emergency plan completed for the dam?			
a. Posted in the gatehouse?			
(17) Other?			

D. Stilling Basin

(1) Do concrete surfaces show:			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Exposed reinforcement?			
(2) Do joints show:			
a. Displacement or offset?			
b. Loss of joint material?			
c. Leakage?			
(3) Do energy dissipaters show:			
a. Signs of deterioration?			
b. Are they covered with debris?			
(4) Other?			

ITEM	YES	NO	REMARKS

3. OUTLET WORKS (continued)

E. Downstream Channel

(1) Is the channel:			
a. Eroding or backcutting?			
b. Sloughing?			
c. Obstructed?			
(2) Is released water:			
a. Undercutting the outlet?			
b. Eroding the embankment?			
(3) Other?			

4. SPILLWAY

A. Description

(1) Location?			
(2) Type of Spillway?			
(3) Size of Spillway?			
(4) Spillway lining?			
(5) Is there a weir?			
(6) Is the spillway in good condition?			
(7) Any drains?			
a. Describe the condition of drains.			

B. Does spillway show:

(1) Any cracking concrete?			
(2) Any spalling concrete?			
(3) Any exposed reinforcement in the concrete?			
(4) Any erosion?			

ITEM	YES	NO	REMARKS

4. SPILLWAY (continued)

4. B. Does spillway show: (continued)

(5) Any slope sloughing?			
(6) Any obstructions?			
(7) Displacement or offset joints?			
(8) Loss of joint material?			
(9) Leakage at the joints?			
(10) Other?			

C. Do the energy dissipaters show:

(1) Signs of deterioration?			
(2) Any cracking?			
(3) Any spalling?			
(4) Any exposed reinforcement?			
(5) Are they covered with debris?			
(6) Other?			

D. Has release water:

(1) Eroded the embankment?			
(2) Undercut the outlet?			
(3) Eroded the downstream channel?			
(4) Other?			

E. Emergency Spillway

(1) Is there an emergency spillway?			(If YES, describe)

ITEM	YES	NO	REMARKS

5. RESERVOIR CONTROL

A) Recent upstream development?			
B) Recent downstream development?			
C) Slides in reservoir area?			
D) Change in reservoir operation?			
E) Large impoundment upstream?			
F) Any debris in the reservoir?			
G) Other?			

6. INSTRUMENTATION

A) List type(s) of instrumentation:			
B) In good condition?			
C) Read periodically?			
D) Is data available?			
E) Include all data gathered since last report.			

7. DOWNSTREAM CONDITION

A. Downstream Land Use.

This dam was inspected by:

Additional comments and recommendations.

APPENDIX C

DISTRIBUTION LIST

O&M MANUAL DISTRIBUTION LIST

WILLOW CREEK DAM

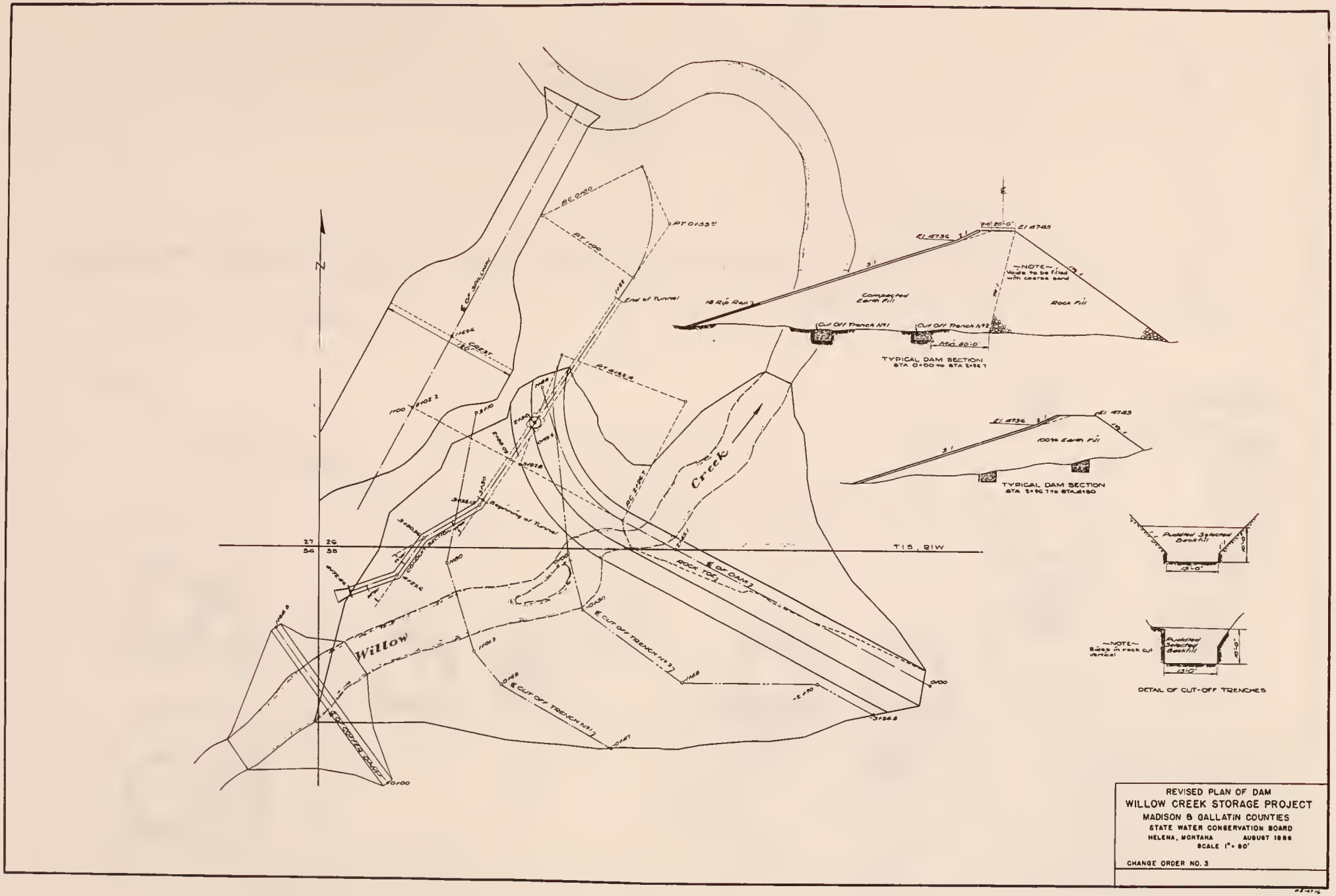
		Number Of Copies
1.	State Water Projects Bureau Glen McDonald Greg Ames Art Taylor (2) Bob Arrington Bob Clark Delores Eustice	7
2.	DNRC Information Services Section	1
3.	DNRC Bozeman Regional Office Scott Compton	1
4.	DNRC Dam Safety	1
5.	Water Users LeRoy Miller -- President Robert C. Rice -- Vice President Trudy McLean -- Secretary/Treasure Barry McLean -- Dam Operator	4
6.	State Library -- Attn: Roberta Gebhardt	4
7.	Extra	2
TOTAL		20

APPENDIX D

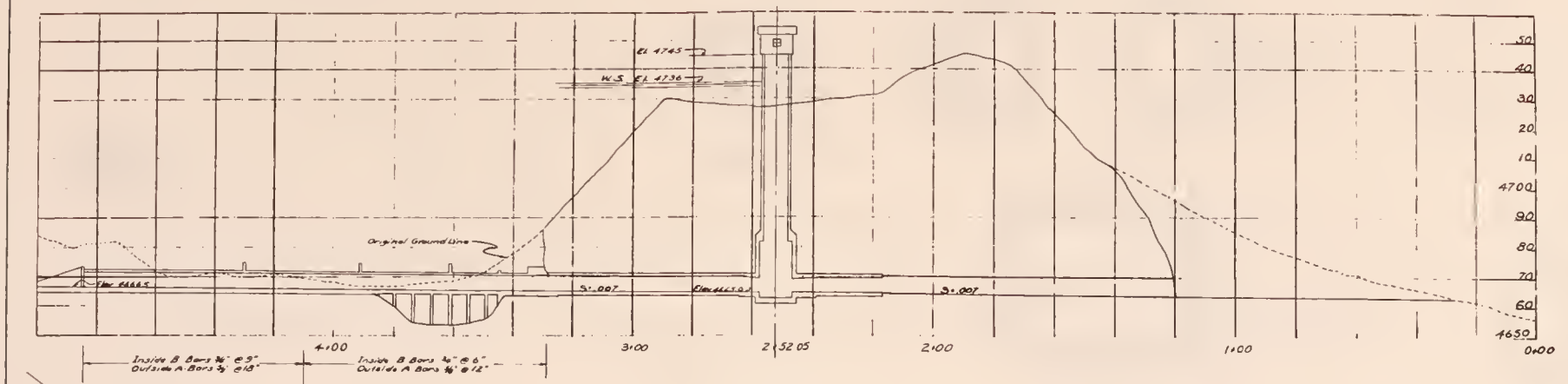
PROJECT DRAWINGS

(NOTE: These reduced project drawings are design drawings and not "As Builts". These drawing should be used for reference only. The SWPB has the full size project drawings.)

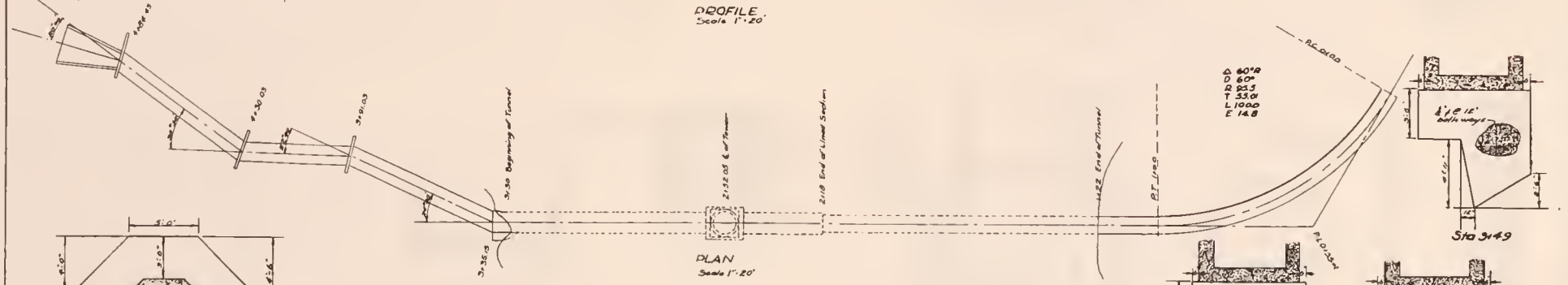
D2 2001



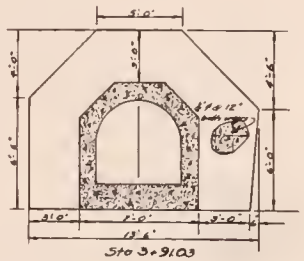
N
Willow
Creek
T1S, R1W
End of Tunnel
Beginning of Tunnel
Compacted Earth Fill
Rock Fill
Cut Off Trench No 1
Cut Off Trench No 2
TYPICAL DAM SECTION
100% Earth Fill
TYPICAL DAM SECTION
Puddled Selected Backfill
DETAIL OF CUT-OFF TRENCHES
REVISED PLAN OF DAM
WILLOW CREEK STORAGE PROJECT
MADISON & GALLATIN COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONTANA
AUGUST 1966
SCALE 1" = 80'
CHANGE ORDER NO. 3



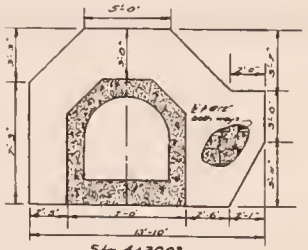
PROFILE
Scale 1"=20'



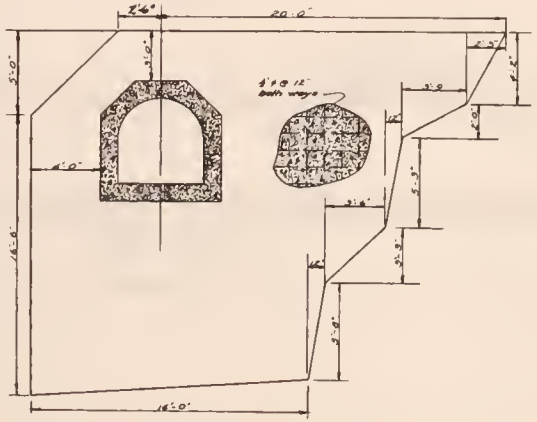
PLAN
Scale 1"=20'



Sta 3+91.03

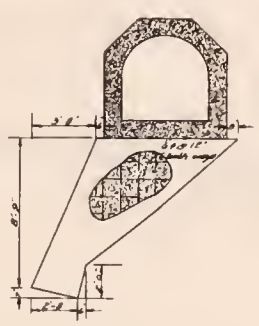


Sta 4+30.03

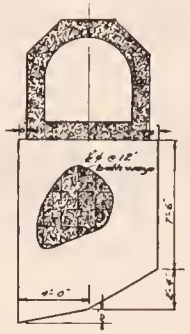


Sta 3+61.0

CUT-OFF WALLS
Scale ½"=1'-0"

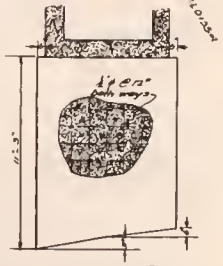


Sta 3+73.75

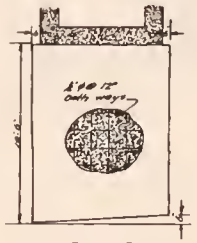


Sta 3+73.5

PIERS
Scale ½"=1'



Sta 3+67.25



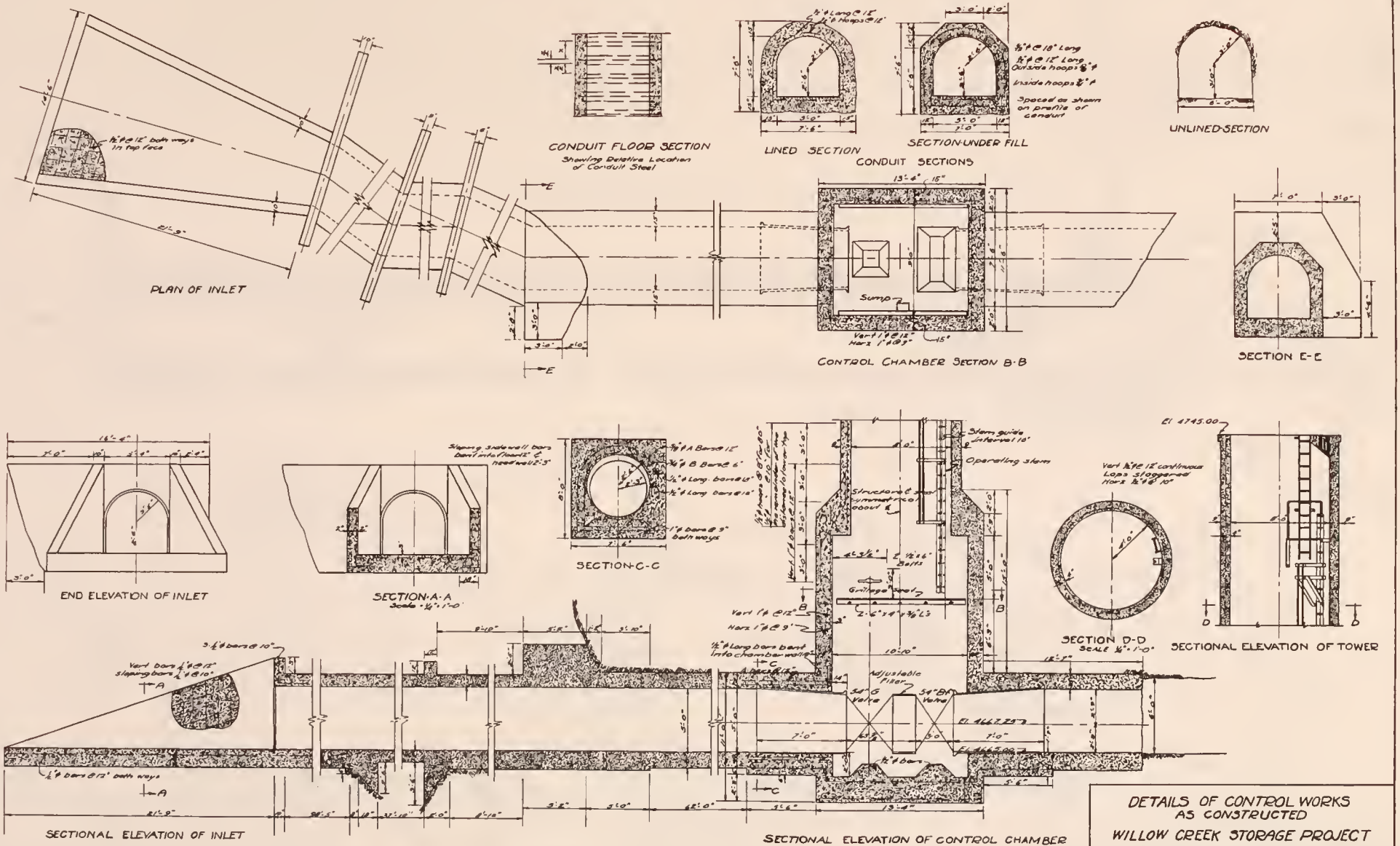
Sta 3+55

Sta 3+49

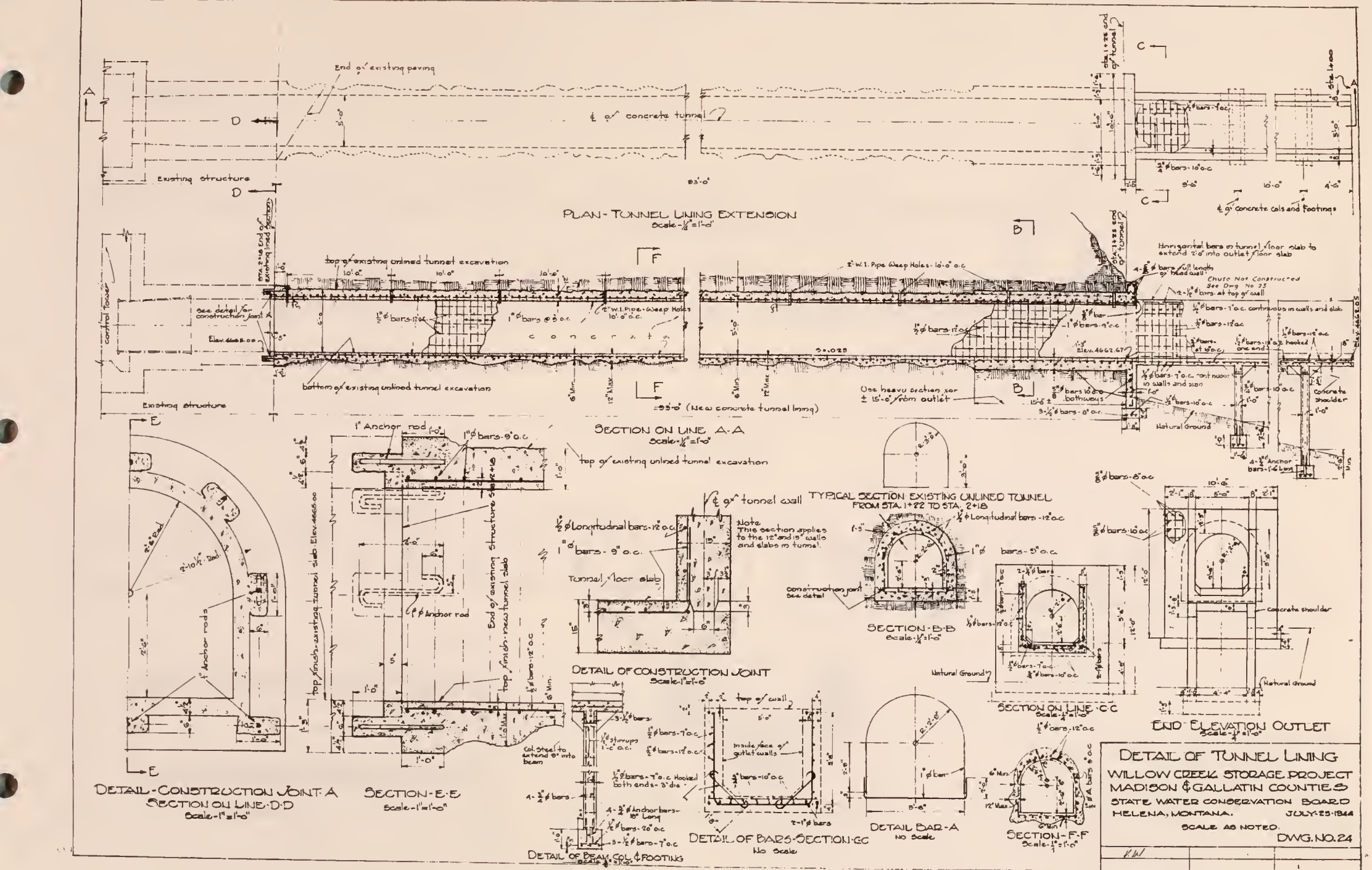
PLAN & PROFILE OF CONTROL WORKS
DETAILS OF CUT-OFFS AND PIERS
AS CONSTRUCTED

WILLOW CREEK STORAGE PROJECT
MADISON & GALLATIN COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONT JUNE 1937
SCALE AS SHOWN
P.W.A. NO. 1002-R DRAWING NO-1

Drawn by	EGF	Traced by	SS		



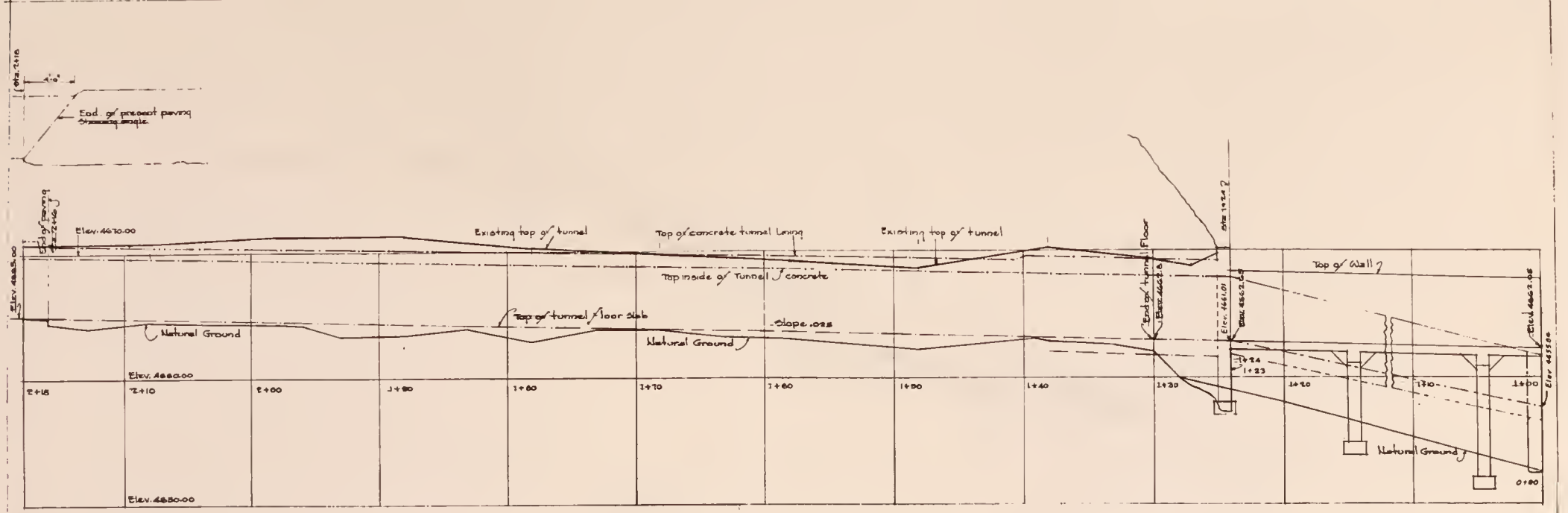
DETAILS OF CONTROL WORKS
AS CONSTRUCTED
WILLOW CREEK STORAGE PROJECT
MADISON & GALLATIN COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONT JULY 1937
Scale ¼"=1'-0"
P.W.A. NO. 1002-R D.W.G. NO. 12



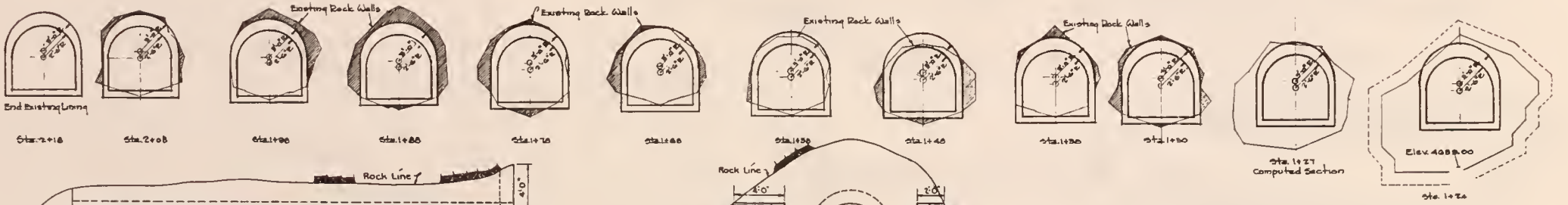
DETAIL OF TUNNEL LINING

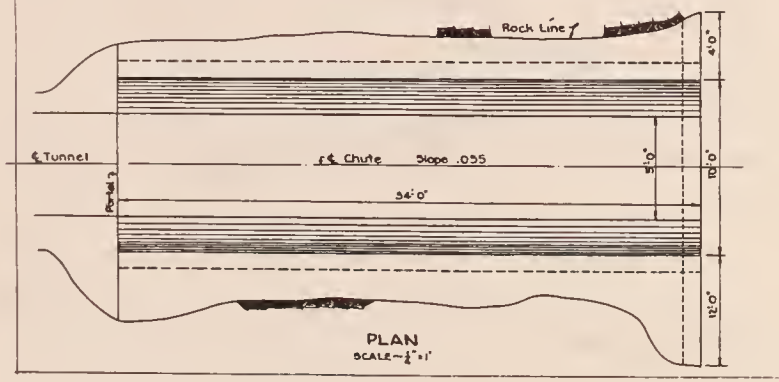
WILLOW CREEK STORAGE PROJECT
MADISON & GALLATIN COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONTANA. JULY-25-1944
SCALE AS NOTED.
DWG. NO. 24

K.W.

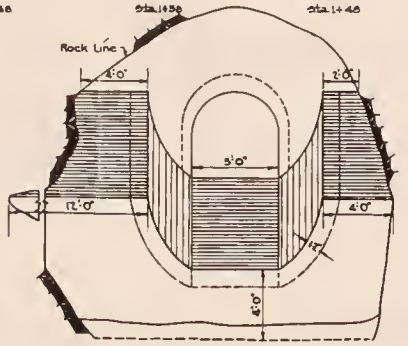


PROFILE OF TUNNEL
Scale-1"=1'-0" Horizontal & Vertical





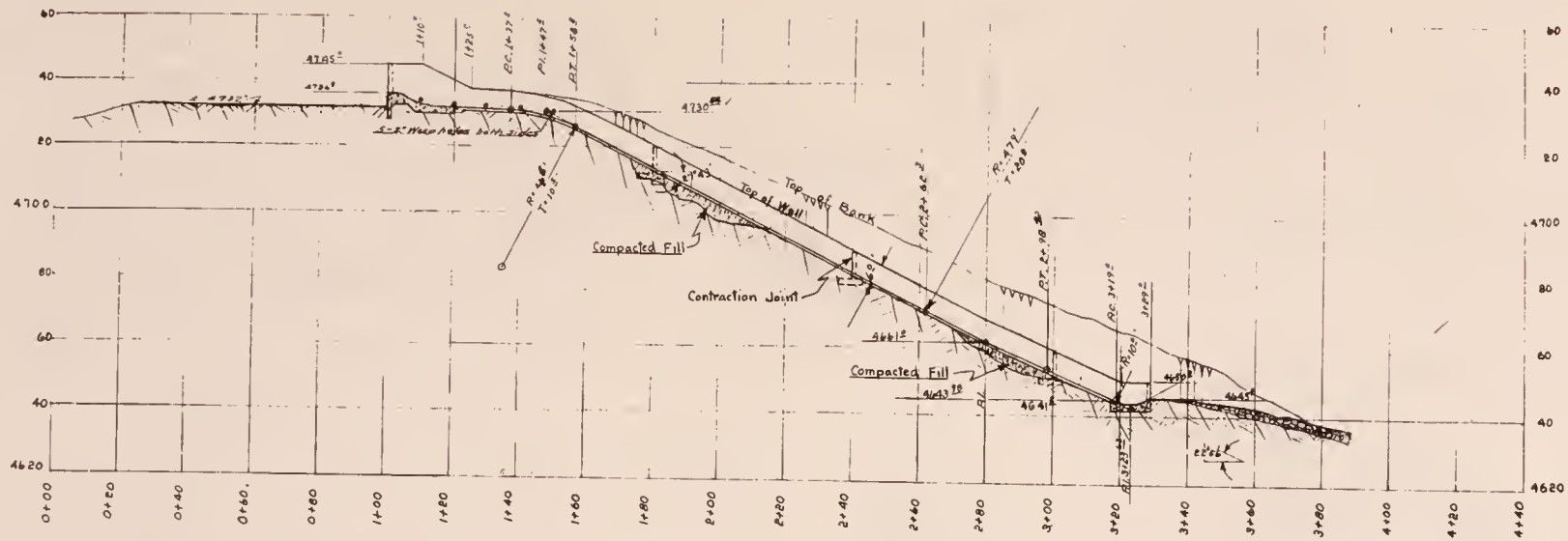
PLAN
SCALE-1/4"=1'



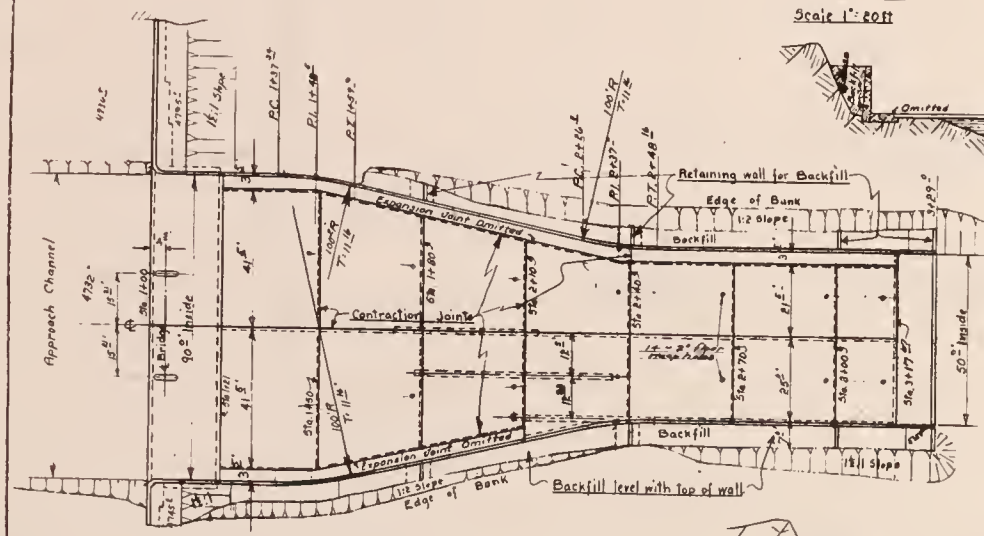
END ELEVATION
SCALE-1/4"=1'

PROFILE AND CROSS SECTIONS
OF TUNNEL LINING
WILLOW CREEK STORAGE PROJECT
MADISON & GALLATIN COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONTANA. JUNE-18-1948
SCALE AS NOTED DWG. No. 25

VW

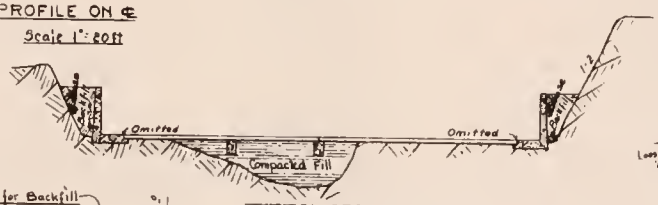


PROFILE ON ℄
Scale 1"=20ft

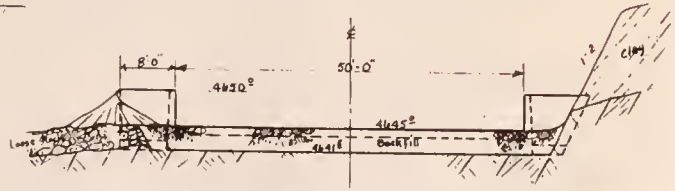


PLAN
Scale 1"=20ft.

All sections looking South

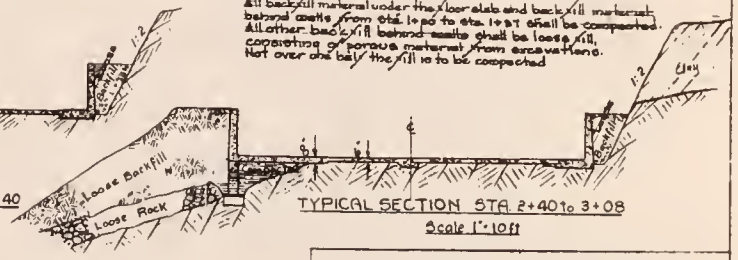


TYPICAL SECTION STA. 1+80 to 2+10
Scale 1"=10ft.



LOWER END ELEVATION
Scale 1"=10 ft.

TYPICAL SECTION STA. 2+10 to 2+40
Scale 1"=10ft

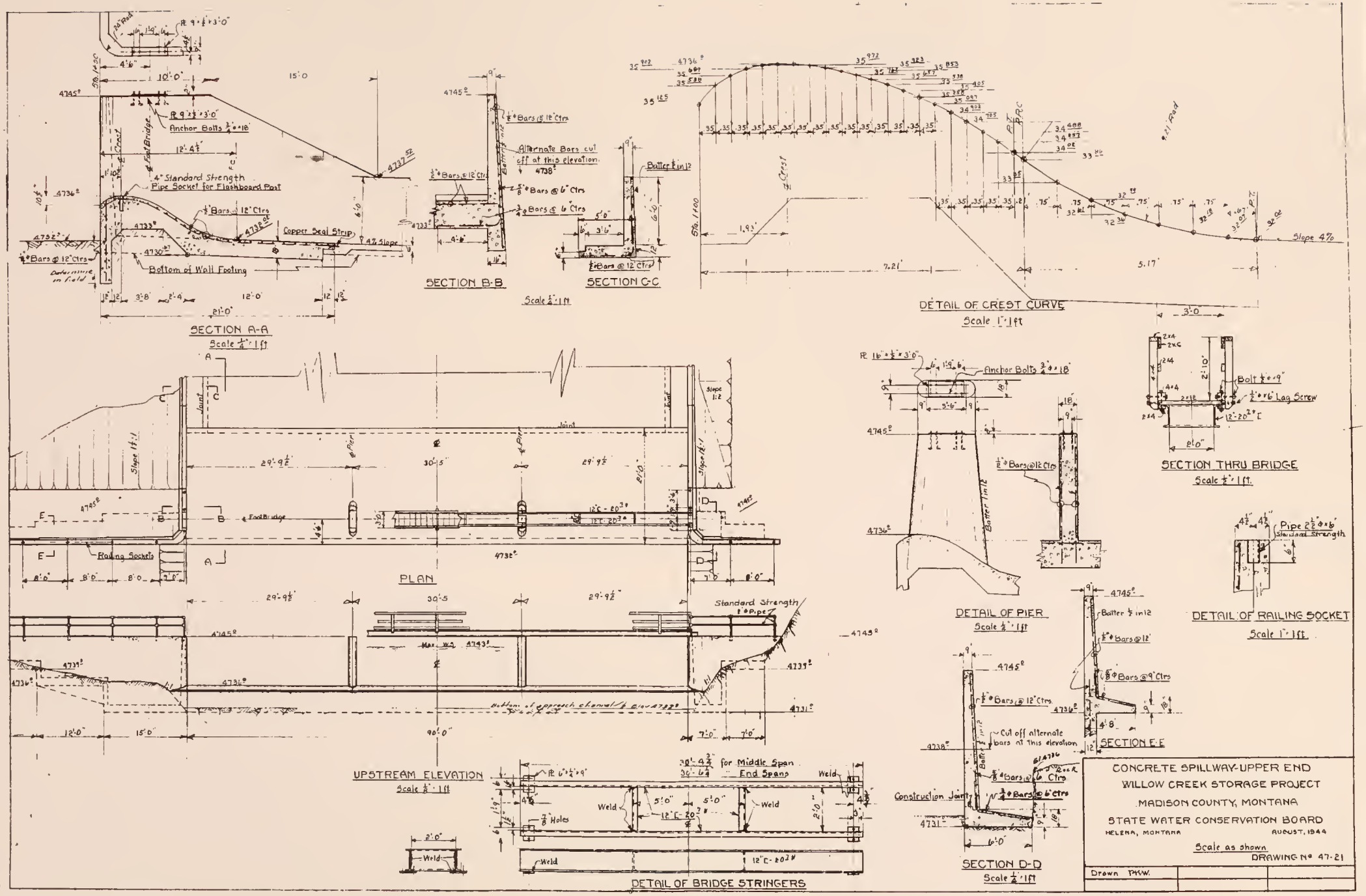


TYPICAL SECTION STA 2+40 to 3+08
Scale 1"=10ft

Note -
All backfill material under the floor slab and backfill material behind walls from sta. 1+20 to sta. 1+97 shall be compacted. All other backfill behind walls shall be loose fill, consisting of pervious material from excavations. Not over one half the fill is to be compacted

TYPICAL SECTION STA 1+21 to 1+80
Scale 1"=10ft

CONCRETE SPILLWAY
PLAN, PROFILE, & SECTIONS
WILLOW CREEK STORAGE PROJECT
MADISON COUNTY, MONTANA.
STATE WATER CONSERVATION BOARD
HELENA, MONTANA. OCT. 1944
Scale as shown
DRAWING Nº 47-E0
Drawn TMcW.



CONCRETE SPILLWAY-UPPER END
WILLOW CREEK STORAGE PROJECT
MADISON COUNTY, MONTANA
STATE WATER CONSERVATION BOARD
HELENA, MONTANA — AUGUST, 1944
Scale as shown
DRAWING No 47-21

Drawn PKW.		